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FLIGHT TRIALS OF THE LITTON LTN-211 OMEGA NAVIGATION SYSTEM IN A WESSEX HELICOPTER

by

I. D. Birch

January 1981

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FLIGHT TRIALS OF THE LITTON LTN-211 OMEGA NAVIGATION SYSTEM IN A WESSEX HELICOPTER

by

10) I. D. Birch

SUMMARY

The Litton LTN-211 Omega Navigation System (ONS) is currently in service in RAF transport and other aircraft. This Memorandum covers installation and flight trials of a variant of the Service Omega equipment in a Wessex helicopter.

This Memorandum expresses the opinions of the author and does not necessarily represent the official view of the Royal Aircraft Establishment.

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1 INTRODUCTION

Omega is generally regarded as a long-range navigation aid particularly suited to world-wide transport and maritime operations. RN2 Division has been heavily involved in the programme to fit the Litton LTN-211 ONS to RAF fixed-wing aircraft. The LTN-211 ONS has available, although not incorporated in the RAF purchase, a variety of software options, including search and rescue (SAR) and rendezvous programmes, which are relevant to helicopter operation. RAE were tasked to carry out limited flight testing of the ONS in a Wessex helicopter.

Some preliminary skin mapping has taken place on the RAE Sea King helicopter. This is discussed in the Appendix.

2 BRIEF DESCRIPTION OF THE LITTON LTN-211 ONS

A detailed description of the ONS is outside the scope of this Memorandum but the following brief outline is pertinent.

The equipment is an all-weather, world-wide navigation system with a bounded error capability. Operating on three Omega navigation frequencies and signals received from nine world-wide VLF communication stations, the equipment offers all guidance parameters required for great circle navigation. The system provides as outputs present position (latitude/longitude), track angle, ground speed, heading (magnetic, true or gyro), drift angle, cross track and track angle error, desired track, waypoint coordinates, distance to waypoints, estimated time of arrival (ETA), estimated time to destination (ETD), wind direction and velocity, time (GMT) and date. As a backup to the primary Omega/VLF derived mode of operating the system, a dead-reckoning (DR) mode is provided, based on air speed and aircraft heading. The DR mode is automatically selected when the number and quality of received Omega/VLF signals fall below the levels required for accurate navigation.

Synchronisation is automatic and the system aligns itself with Omega/VLF transmissions. After initial entry of position, time and date, selection of stations to be used for navigation is automatic. Signals, from all Omega and VLF transmitters meeting range, signal/noise, etc criteria are used to provide multiple redundancy of information and enhanced accuracy. This method enables maximum position accuracy to be achieved, as account is taken of the quality of the signals, their propagation stability and which stations are least likely to be affected by diurnal transitions.

After initialisation, waypoint information can be entered as latitude/longitude and, when a track is selected, the system automatically navigates from waypoint to waypoint. It is possible to bypass or change a waypoint in flight and several methods of track changing are incorporated to allow for alteration in flight path. The system can provide outputs to the aircraft horizontal situation indicator (HSI) and steering information to an autopilot.

The equipment contains facilities for operator error detection, station deselection and reselection, magnetic, true or gyro heading display, remote ranging, wind update in DR, manual true airspeed (TAS) and heading update in the event of input failure, malfunction code readout with full, self test and gyro (grid) navigation. The equipment is to full ARINC 599 standard.[1]

Software options, particularly appropriate to helicopter operations, include three automatic search patterns:

(a) Ladder pattern
(b) Expanding square
(c) Sector pattern.

The operator selects the required pattern and inserts the pattern parameters via the control and display unit (CDU). Automatic or manual search start facilities are available together with fully automatic pattern flying through autopilot steering signals. Search mode interrupt and re-entry capabilities are included. These options are not, at present, incorporated in service Omega equipments, but could be implemented quickly as a software change. The final standard equipments in service use have sufficient spare computer capacity to include these SAR facilities. More comprehensive details are available in Ref 2.

3 THE FLIGHT TEST ONS EQUIPMENT

The receiver processor unit (RPU) used for the flight tests was loaned to RAE by Litton. It differs from those now in service use only in the software modifications required to cope with the different speed range. These modifications are as follows:

(a) The wind value is set to zero whenever the TAS input is less than 80 kn.

(b) Manual override of TAS input is allowed if the entered value is above 10 kn and below 650 kn.

(c) Manual entry of TAS can be made at any time, and retained during power interrupts. When the entry is made on the ground, it is displayed but not used.

(d) When TAS is less than 80 kn, time-to-go is computed using 100 kn.

(e) Leg switching is computed using 50 kn instead of 100 kn.

(f) In the remote ranging mode, time-to-go is based on actual ground speed; if TAS is less than 80 kn, time-to-go is computed using 100 kn.

(g) Distance is displayed on the CDU in nautical miles and tenths of a nautical mile, with a range of 000.0 to 999.9 n mile.

The remaining items making up the ONS, the CDU and the H-field 'brick' type antenna, were standard service approved items.

4 THE AIRCRAFT INSTALLATION

4.1 The antenna

Two types of antenna can be used in ONS operation: the E-field (capacitance plate) antenna or the H-field (crossed ferrite loop) antenna. Both pose installation problems. The H-field antenna is sensitive to noise emanating from the aircraft's power supplies and, in the case of the RAE Wessex, from the experimental power supplies fitted to the aircraft.

The main problem is the 400 Hz (nominal) fundamental frequency of power generation. The 25th and upwards harmonics of frequencies in the range 390-410 Hz fall in the Omega band (10-14 kHz) and changes in the primary frequency, which are common with varying aircraft load conditions, can result in severe interference to Omega equipment, especially as the return current path is the aircraft skin. Large currents in the aircraft skin have attendant large magnetic fields which couple to the antenna and reduce the signal/noise ratio. It is therefore of paramount importance to choose a site for an H-field antenna which is electrically as 'quiet' as possible. If such a site can be found using skin mapping techniques (briefly explained later in this Memorandum), an H-field antenna should be used in preference to the second type available.

The E-field antenna is subject to 'precipitation static' effects when the aircraft moves through electrically charged particles in certain types of cloud. Precipitation static produces noise which is random in nature and can result in the Omega RPU being swamped with noise for long periods of time. The effects are more fully discussed in Ref 3.

A helicopter poses particular noise problems as considerable electrical power is generated effectively at the centre of a very small aircraft with poor electromagnetic shielding. These problems were exacerbated on the RAE Wessex XL 728 as the aircraft is fitted with auxilliary power generators for experimental purposes.

4.2 Skin mapping

The aircraft was skin mapped using a standard Omega antenna as a magnetic probe. The antenna was connected via a test unit to the Omega PPU and also to a low frequency spectrum analyser (Hewlett Packard type 3580A) operating on the specific Omega frequencies in the 10-14 kHz band and sampling bandwidths of 30 or 10 Hz. The antenna was powered either from the test unit (internal batteries) or, via the test unit, from a standard Omega RPU which enabled direct observation of Omega performance. The test unit allows individual loops in the antenna to be connected to the spectrum analyser. With the aircraft in a condition approximating as closely as possible to normal flight conditions, ie all engines, generators, electrical and radio equipment running, the antenna was held against the aircraft skin while the signal/noise characteristics of a possible site were examined by means of the spectrum analyser and the Omega. Other possible sites were investigated in turn until an electrically quiet site was found. The antenna was then fixed to the site using adhesive tape and the Omega performance was checked using standard Omega equipment. Test results were compared with calibration results taken in the vicinity of an electrically 'dead' aircraft.

Five possible sites were examined (Fig 1). The optimum site found was position 5, on the top rear fuselage just forward of the tail rotor folding hinge. Several positions were investigated forward of position 1, but noise was so bad that no readings were noted. Position 2 was unusable due to noise spikes from pulsed anti-collision light. Skin mapping results are given in Table 1.

It was apparent that much of the noise was generated by the additional generators carried on this aircraft for experimental purposes. There appeared to be very little noise from the aircraft's own inverters at position 5.

It was also found, during skin mapping, that if the antenna was lifted away from the aircraft skin by as little as 20 mm the magnetic coupling between the noise currents in the aircraft skin and the antenna was modified and an improvement in received signal/ noise ratio was effected.

A small top hat assembly was designed to enable the antenna to be mounted horizontally in normal flight at position 5. A 20 mm thick non-conducting block was also designed to check the effect of lifting the antenna away from the aircraft skin.

4.3 The RPU and CDU

The RPU and CDU were mounted on RAE 'RADRAC' trays in a stretcher assembly on the port side of the aircraft cabin. Power for the ONS (115V, 1∅, 400 Hz, 66 W; and 28V dc, 1 A) was taken from the aircraft experimental supplies. The ONS was rate-aided from the aircraft compass and by manually inserting true airspeed.

5 FLIGHT TESTING

The trial was conducted at flight levels between zero and 3000 ft at a constant speed of 90 kn. Outward flight legs were flown on a constant heading of 260 (true) from RAE and return legs on the reciprocal heading. Accuracy was determined by reading Omega fixes when overhead known landmarks (the Wessex is fitted with a vertical sight, enabling overhead positions to be accurately determined). A total of $7\frac{1}{2}$ h of flight trials (four sorties) have been flown. The first three sorties were flown with the antenna mounted on the aircraft skin, and the final sortie with the insulating block interposed between the mounting plate and the antenna. On this last sortie Omega station 1 (Norway) was off the air for routine maintenance.

Results were hand logged on an RAE designed Omega/VLF reporting form (Table 2). The following parameters were logged at each position fix:

(i) Time GMT.

(ii) Omega position latitude/longitude.

(iii) Omega stations available for use.

(iv) Omega signal quality. (The ONS outputs a 2-digit number between 00 (no signal) and 40 (max acceptable signal) related to signal/noise ratio for each frequency of each station received.)

(v) Omega stations and frequencies used by the ONS for navigation. The ONS outputs an octal number between 0 (no usable frequency) and 7 (three usable frequencies) for each Omega station.

(vi) VLF stations received.

(vii) VLF station signal quality.

(viii) VLF station mode of modulation.

(ix) Reference position (latitude/longitude).

(x) Received signal quality. (The ONS outputs a 2-digit number between 00 (ideal signal quality) and 24 (NO signals).)

6 RESULTS

6.1 First flight

The first flight took place on 1 May 1980 with take-off at 1410 GMT and landing at 1607 GMT. The trial was conducted at a height of 2500 ft. Although the signal reception was affected by aircraft generated noise, Omega operation was good. All Omega stations, with the exception of Hawaii (not received in UK due to range) and La Reunion (very weak in UK), were received and VLF reception was good with three stations available for most of the trial, at or near, maximum usable signal strength (Table 2).

Position accuracy was very good with a mean radial error of less than 1 n mile (Fig 2).

6.2 Flight 2 (2 May 1980; take-off 0913, landing 1040)

This trial was conducted at low level, 100-700 ft, and had to be curtailed due to rapidly deteriorating weather conditions with low cloud, rain and poor visibility.

There was no marked deterioration in Omega performance due to the low altitude or persistent 'in cloud' operation. A minimum of 13 Omega lines of position (LOPs) were received at all times and VLF reception was good. Poor visibility made accurate determination of overhead positions difficult, but positional accuracy appeared to be good with a terminal error of approximately 0.5 n mile.

6.3 Flight 3 (7 May 1980; take-off 1143, landing 1350)

This trial was conducted at heights between 1000 and 3000 ft and included an emergency air traffic diversion which entailed rapid manoeuvring of the aircraft. Signal reception and position accuracy were again good and the rapid manoeuvres had no apparent effect on Omega accuracy.

The accuracy plot for this flight (Fig 3) shows the effect of a sudden ionospheric disturbance (SID) on Omega operation. A SID is the result of depression of the ionosphere caused by bursts of X-rays from solar flares. The electron density of the part of the layer facing the sun suddenly increases after which it gradually returns to its previous value. The onset of the effect is usually complete within 5-10 min and the decay can last an hour or longer. The phase velocity of the received signal is affected and significant errors can result. The effects are totally unpredictable and it is impossible to compensate for them. Their effect is equivalent to a reduction in propagation time. Not all paths from all stations are affected and multiple redundancy of signal reception tends to reduce the error effects. Only daylight paths are affected.

During the period of this trial the RN2 ground monitor was recording all receivable Omega parameters and the effects found on the trial were directly correlated with monitor records.

6.4 Flight 4 (15 August 1980; take-off 0944, landing 1129)

This trial was conducted at a height of 1500 ft with the antenna mounted on a 20mm insulating block to verify the apparent improvement in signal/noise ratio found during skin mapping (see section 4.2). Omega Station 1 (Norway) was off the air for maintenance for the period of the trial and Station 2 (Liberia) suffered a failure of approximately 15 min during the return leg. The loss of these two stations (the stations received at greatest amplitude in UK) had no noticeable effect on Omega accuracy, which was again very good. There was an improvement of an average of about 5 dB in received signal/noise ratio when compared with results obtained without the insulating block (see Tables 2 and 3). VLF was again good with a minimum of two stations (and often three) available at, or near, maximum strength. Accuracy results are given in Fig 4.

7 CONCLUSIONS

Omega operation, using a standard service LTN-211 Omega (ARI 23314) equipment with minimal software modification, was shown to be viable in a Wessex aircraft. It would be necessary, however, to fit some form of air data computer to feed Omega with accurate TAS if the equipment tested were to be procured for service use. There are other versions of the equipment which do not require velocity rate-counting as the aircraft velocity is derived from the rate of change of phase. Operational altitude has, as expected, little or no effect on Omega performance. It would be vital to carry out a detailed skin mapping exercise (preferably) on more than one aircraft in a fleet before a major installation exericse was contemplated.

Some SAR and ASW programmes are already available for use in the LTN-211, but none are, to date, incorporated in standard service equipments. There is enough spare computer capacity in the standard service sets to accommodate the SAR programmes described in section 2. Other SAR and ASW programmes could easily be incorporated, but might need additional computer memory or modification of existing programmes. Omega with the above software would greatly enhance the navigational performance of both RAF and Navy helicopters.

Omega reception on the RAE Wessex is affected by noise generated by the aircraft's experimental power supplies. These power supplies are not carried in standard service aircraft and Omega operations should, therefore, be improved. Service aircraft do, however, carry electrical and radio equipment not fitted to the RAE aircraft. The effect of this equipment on Omega performance could only be ascertained by careful skin mapping of each type of aircraft to be fitted.

In operations around UK, the loss of one or two Omega stations, has been shown to have little or no effect on Omega accuracy. The effects in other theatres of operation would depend on the relative geometry of the aircraft and the ground stations received and the received signal strengths from these stations.

Raising the antenna away from the aircraft skin results in a useful gain in received signal/noise ratio on the RAE Wessex. It is possible that the effect could be similar on other helicopter installations but this could only be ascertained by careful skin mapping.

Appendix

SKIN MAPPING RESULTS ON THE RAE SEA KING HELICOPTER XU 371

Some preliminary skin mapping was performed for the RAE Sea King helicopter on 20 June 1980. The aircraft is 'non-standard' in that it has been modified for experimental use and contains no radar. Six positions on the fuselage were investigated (Fig 5). Positions 1, 3, 7, 8 and 9 were so noisy that no readings were taken. Position 2 was severely affected by noise from the aircraft's inverters, and from the experimental inverters, affecting the 13.6 kHz Omega signal. The most promising positions found were on the aircraft's horizontal stabiliser section (Fig 5). Two positions, 4 and 5 on the underside of the stabiliser, were investigated with one, position 6, on the top of the stabiliser. Position 6 was found to be unusable due to pick up from the anti-collision light on top of the pylon. Position 4, inboard on the underside of the stabiliser, was marginally affected when the rotors were engaged, but position 5 appeared to be totally unaffected. Skin mapping results, for positions 4 and 5, are given at Table 4.

This aircraft is very non-standard and the results are not necessarily applicable to 'standard' Sea King helicopters.

An antenna mounted on the underside of the stabiliser could affect the longitudinal pitching moment of the aircraft. This could affect the aircraft handling in terms of fore and aft control and/or stability. In view of the above, it was decided not to proceed with an experimental Omega installation on the RAE aircraft. This does not mean that the LTN-211 ONS is not viable in Sea Kings. On the contrary, it is suggested that such an installation could be a useful addition to the aircraft. But it would be necessary first, to carry out a skin map of a typical operational aircraft, and to follow that with a trial installation if a promising antenna site could be found.

Table 1

SKIN MAPPING RESULTS FOR MK 2 WESSEX XL 728

Aircraft No. XL 728				Skin mapping data sheet								
Aircraft heading: 030					Aircraft: Wessex Mk 2							
Loop No.	Signal-to-noise ratio at (1) dB									Airframe location	Spectrum analyser bandwidth	Configuration (2)
	10.2 kHz			11.33 kHz			13.6 kHz					
	N	S + N	Δ	N	S & N	Δ	N	S + N	Δ			
1	-85	-63	22	-85	-62	23	-80	-62	18	Ambient	30 Hz	Ant 50 ft from aircraft
2	-85	-53	32	-85	-63	32	-82	-52	30			
1	-85			-80			-82			1	" "	No power
2	-80			-80			-80					
1	-60			-68			-67			1	" "	Inverters aircraft on experiment
2	-48			-51			-60					
1	Large spikes caused by anti-collision									2	" "	8
2	Light (unusable)											
1	-60			-62			-65			3	" "	8
2	-51			-56			-57					
1	-65			-65			-75			4	" "	8
2	-50			-52			-55					
1	-73			-75			-75			5	" "	8
2	-66			-66			-62					

NOTES: (1) N = noise only, S + N = signal plus noise, Δ = difference

(2) Configurations defined as follows:

1: Engines on
2: Generator on main
3: Generators on auxiliary
4: Electronics on
5: Lights on
6: Air conditioning on
7: Fan on
8: All on

Table 2

LITTON OMEGA/V.L.F REPORTIN…

AIRCRAFT TYPE WESSEX **No** XL728 **UNIT** RAE **DATE** 1.5.80 **ROUTE** 260°(T) AND…

OMEGA POSITION

GMT (1–5)	LAT (6–10)	N/S (11)	LONG (12–17)	E/W (18)	Station Ch'k (Note 1) 1 (19)	2 (20)	3 (21)	4 (22)	5 (23)	6 (24)	7 (25)	8 (26)
1200	51162	N	00462	W			X		X	C		
1400	51160	N	00462	W			X		X	C		
1410	51173	N	00491	W			X		X	C		
1418	51159	N	00562	W			X		X	C		
1420	51149	N	01053	W			X		X	C		
1425	51141	N	01174	W			X		X	C		
1427	51128	N	01274	W			X			C		
1430	51114	N	01397	W			X		X	C		
1433	51103	N	01494	W			X		X	C		
1439	51089	N	02018	W			X		X	C		
1442	51077	N	02134	W			X		X	C		
1444	51070	N	02196	W			X		X	C		
1447	51058	N	02294	W			X		X	C		
1451	51045	N	02402	W					X	C		
1454	51033	N	02513	W			X		X	C		
1458	51018	N	03027	W			X		X	C		
1500	51023	N	03023	W			X		X	C		
1505	51035	N	02518	W			X		X	C		
1511	51050	N	02395	W			X		X	C		
1516	51057	N	02298	W			X		X	C		
1522	51072	N	02203	W			X		X	C		
1526	51081	N	02132	W			X		X	C		
1531	51093	N	02032	W			X		X	C		
1537	51106	N	01505	W			X		X	C		
1541	51118	N	01413	W			X		X	C		
1547	51131	N	01295	W			X		X	C		
1553	51143	N	01192	W			X		X	C		
1557	51155	N	01074	W			X		X	C		
1603	51163	N	00588	W			X		X	C		
1607	51172	N	00498	W								
1609	51164	N	00469	W								

OMEGA SIGNAL QUALITY

GMT	1: 10.2	1: 13.6	1: 11.3	2: 10.2	2: 13.6	2: 11.3	3: 10.2	3: 13.6	3: 11.3	4: 10.2	4: 13.6	4: 11.3	5: 10.2	5: 13.6	5: 11.3	6: 10.2	6: 13.6	6: 11.3	7: 10.2	7: 13.6	7: 11.3	8: 10.2	8: 13.6	8: 11.3
1200	√	√	√	28	25	√	12	9	11	16	12	15	13	13	14				22	21	23	14	13	12
1400	√	√	√	28	√	√	12	9	10	14	12	13	13	13	15				20	22	23	11	12	11
1410	√	√	√	√	25	25	11	8	11	16	14	14	13	11	11				19	23	5	12	15	11
1418	√	√	√	√	√	√	10	11	10	16	14	12	11	14	11				25	25	25	12	16	11
1420	√	√	√	21	21	21	11	10	8	14	16	12	12	15	9				20	21	20	13	13	6
1425	√	√	√	22	22	22	11	10	10	14	13	12	12	16	11				20	24	20	12	15	12
1427	√	√	√	26	27	25	12	8	10	13	13	12	11	13	12				18	24	18	15	13	13
1430	√	√	25	27	30	15	12	11	11	13	15	12	11	14	12				19	24	13	13	14	11
1433	√	√	√	25	27	21	12	11	11	12	13	13	12	14	10				19	23	17	13	12	14
1439	√	√	√	29	30	26	13	11	11	14	14	14	13	13	11				17	22	21	10	15	14
1442	√	√	√	26	20	27	12	7	11	14	12	14	12	10	10				18	16	19	12	11	13
1444	√	√	√	28	25	29	9	11	7	14	13	13	11	11	11				19	18	20	13	14	11
1447	√	√	√	26	25	28	13	8	12	12	15	15	11	13	11				17	24	23	14	12	14
1451	√	√	√	20	28	26	13	9	12	13	13	13	12	12	11				20	19	17	12	13	15
1454	√	√	√	30	29	28	12	10	13	13	13	14	13	11	8				20	20	20	13	13	15
1458	√	√	√	20	29	26	13	11	12	13	11	14	12	12	9				17	19	20	13	13	12
1500	√	25	√	30	16	28	12	11	12	12	12	13	12	12	10				19	15	21	14	14	12
1505	√	26	√	√	26	√	12	11	9	13	9	14	12	9	11				20	14	21	13	12	13
1511	√	√	√	√	√	√	11	11	12	14	12	14	11	11	11				19	21	20	12	15	14
1516	√	√	√	27	27	30	11	10	12	14	13	12	11	12	11				20	23	24	14	13	14
1522	√	√	√	30	30	30	12	11	12	14	13	14	11	11	11				18	23	20	13	13	11
1526	√	√	√	√	24	30	11	11	9	15	13	12	10	11	11				19	17	20	13	13	15
1531	√	√	√	√	30	√	12	11	12	14	11	15	11	11	10				20	14	21	13	13	11
1537	√	√	√	29	26	21	12	10	11	13	13	15	12	10	9				17	19	20	12	13	11
1541	√	√	√	29	√	30	11	10	12	13	12	14	12	13	11				20	29	20	12	14	13
1547	√	√	√	√	√	√	12	11	12	13	13	15	10	15	12				17	21	21	12	13	13
1553	√	√	√	28	√	√	12	11	9	13	13	15	11	13	10				17	23	20	10	12	14
1557	√	√	√	√	√	√	12	10	10	13	13	13	10	13	10				15	22	23	10	14	11
1603	√	√	√	√	√	√	10	9	11	10	13	12	12	12	9				14	22	21	11	14	11

(Station 6 column, written vertically:) USED FOR ANTENNA CALIBRATION

STNS USED (AUX 3)

GMT	1 (51)	2 (52)	3 (53)	4 (54)	5 (55…)
1200	7	7	0	7	0
1400	7	7	0	7	3
1410	7	7	0	7	2
1418	7	7	0	6	0
1420	7	7	0	7	2
1425	7	7	0	7	2
1427	7	7	0	7	2
1430	7	7	0	7	0
1433	7	7	0	7	0
1439	7	7	0	7	0
1442	7	7	0	5	0
1444	7	7	0	7	0
1447	7	7	0	7	0
1451	7	7	4	5	4
1454	7	7	0	7	0
1458	7	7	0	5	0
1500	7	7	0	5	6
1505	7	7	0	5	0
1511	7	7	0	7	0
1516	7	7	0	7	0
1522	7	7	0	7	0
1526	7	7	0	7	0
1531	7	7	0	5	0
1537	7	7	0	7	0
1541	7	7	0	7	0
1547	7	7	0	2	0
1553	7	7	0	7	0
1557	7	7	0	6	0
1603	7	7	0	7	0

REF. POSITION CODE 1 VISUAL REF 2 ____ 3 ____ 4 ____ 5 ___

NOTE 1. MARK WITH X IF STATION NOT AVAILABLE, 'D' IF DESELECTED BY EQUIPMENT, 'M' IF M…

NOTE 2. CIRCLE V.L.F. STATION No. IF FLASHING √ = 40

/ 1

Table 2

OMEGA/V.L.F REPORTING FORM

1st OMEGA TEST FLIGHT.

-5.80 ROUTE 260°(T) AND RECIP^L OBSERVER (S) I.D.B. LER. PAGE 1 OF 1

QUALITY (41) 11.3	7: 10.2 (45)	7: 13.6 (46)	7: 11.3 (47)	8: 10.2 (48)	8: 13.6 (49)	8: 11.3 (50)	STNS USED (AUX 3) 1–8 (51–58)	V.L.F. (AUX 5) STNS (NOTE 2) (59–62)	SIGNAL QUALITY (63–66)	MOD N (67–70)	REFERENCE POSITION LAT (71–75)	N/S (76)	LONG (77–82)	E/W (83)	CODE (84)	QUALITY INDEX	REMARKS
4	22	21	23	14	13	12	77070071	3568	2 ✓ ✓ 17	4444	51162	N	00462	W	1	02	SWITCH ON. EXP^L.
																	POWER FAIL. RETURN
																	TO PAD.
15	20	22	23	11	12	11	77073071	3568	2 ✓ ✓ 17	4442	51162	N	00462	W		02	TAXY/T/OFF
11	19	23	5	12	15	11	77072074	1568	18 ✓ ✓ 19	0442	51171	N	00483	W		02	TAS SET 94kn
11	25	25	25	12	16	11	77060074	1356	19 10 ✓ ✓	0244	51160	N	00585	W		01	
9	20	21	20	13	13	15	77072071	1356	19 4 29 ✓	0244	51151	N	01061	W		01.	
11	20	24	20	12	15	12	77072073	1568	19 ✓ ✓ 0	0444	51141	N	01180	W		01	
12	18	24	18	15	13	13	77072071	1356	19 2 29 ✓	0244	51129	N	01285	W		00	
12	19	24	13	13	14	11	77070074	1356	14 2 ✓ ✓	4244	51115	N	01400	W		01.	
10	19	23	17	13	12	14	77070075	1256	16 20 ✓ ✓	4444	51107	N	01495	W		01.	
11	17	22	21	10	15	14	77070071	1568	6 30 ✓ 08	2442	51090	N	02022	W		01	FL 3000'
10	18	16	19	12	11	13	77050071	1456	21 15 ✓ ✓	0044	51080	N	02124	W		01	
11	19	18	20	13	14	11	77070074	1567	2 ✓ ✓ 2	2442	51069	N	02196	W		01.	
11	17	24	23	14	12	14	77070075	3568	4 ✓ ✓ 18	2440	51060	N	02295	W		01	
11	20	14	17	12	13	15	77454073	1568	21 ✓ ✓ 2	0442	51049	N	02395	W		01	F.L 2500'
8	20	20	20	13	13	15	77070075	1456	22 11 ✓ ✓	0444	51034	N	02514	W		01	
9	17	19	20	13	13	12	77050077	1568	22 ✓ ✓ ✓	0444	51017	N	03025	W		01	TURN TO RECIP. HDG.
10	19	15	21	14	14	12	77056077	1569	26 ✓ ✓ 12	0440	51020	N	03025	W		01	
11	20	14	21	13	12	13	77050075	1567	25 ✓ ✓ 2	2442	51034	N	02514	W		01	
11	19	21	20	12	15	14	77070075	1456	25 2 ✓ ✓	2244	51049	N	02395	W		01	
11	20	23	24	14	13	14	77070075	1356	25 10 ✓ ✓	2444	51057	N	02295	W		01	
9	18	23	20	13	13	11	77070074	1568	25 ✓ ✓ 0	2440	51072	N	02196	W		00	
11	19	17	20	13	13	15	77070076	1456	25 0 ✓ ✓	2244	51081	N	02124	W		00	
10	20	14	21	13	13	11	77050074	1567	29 ✓ ✓ 2	0444	51092	N	02022	W		01	
9	17	19	20	12	13	11	77070074	4567	14 30 ✓ 0	0442	51107	N	01495	W		01	
11	20	29	20	12	14	13	77070075	3567	14 ✓ ✓ 0	4444	51117	N	01400	W		01	
12	17	21	21	12	13	13	77020077	1568	21 ✓ ✓ 13	0440	51129	N	01285	W		01	
10	17	23	20	10	12	14	77070077	1557	21 ✓ ✓ 16	0444	51141	N	01180	W		01	
10	15	22	23	10	14	11	77060070	1568	10 29 ✓ 10	4444	51152	N	01061	W		01	
9	14	22	21	11	14	11	77070033	1567	10 ✓ ✓ 17	2440	51162	N	00585	W		01	
											51162	N	00482	W		01	TOUCH DOWN
											51162	N	00462	W	1	01.	

USED FOR ANTENNA CALIBRATION

4 ---- 5 ---- 6 ---- 7 ---- 8 ---- 9 ----

BY EQUIPMENT, 'M' IF MANUALLY DESELECTED, 'C' IF CALIBRATION CHANNEL.

Table 3

LITTON OMEGA/V.L.F REPORTING FO

AIRCRAFT TYPE WESSEX   No. XL 728   UNIT RAE   DATE 15.8.80   ROUTE [illegible] (T) AND RECIP.

GMT	OMEGA POSITION LAT	N/S	LONG	E/W	STATION CH'K (NOTE 1) 1	2	3	4	5	6	7	8	SIGNAL QUALITY 1 (10.2 13.6 11.3)	2 (10.2 13.6 11.3)	3 (10.2 13.6 11.3)	4 (10.2 13.6 11.3)	5 (10.2 13.6 11.3)	6 (10.2 13.6 11.3)	7 (10.2 13.6 11.3)	8 (10.2 13.6 11.3)	STNS USED (AUX 3) 1	2	3	4	5	6	7	8
1–5	6–10	11	12–17	18	19	20	21	22	23	24	25	26	27–29	30–32	33–35	36–38	39–41	42–44	45–47	48–50	51	52	53	54	55	56	57	58
0928	51162	N	00462	W	M		X				C	X		√ √ √	12 10 8	20 23 21	15 17 15	20 25 10		12 14 8	0	7	0	7	7	6	0	2
0940																												
0944	51173	N	00491	W			X				C			√ √ √	11 12 11	20 19 20	16 17 17	21 22 24		15 16 16	0	7	0	7	7	7	0	7
0945	51158	N	00576	W			X				C			√ √ √	12 11 12	19 19 17	15 16 17	21 21 23		15 16 15	0	7	0	7	7	7	0	7
0949	51151	N	01058	W			X				C			√ √ √	12 12 12	19 20 18	14 15 13	22 22 24		13 12 12	0	7	0	7	6	7	0	1
0955	51138	N	01178	W			X				C	X		√ √ √	11 10 9	21 21 19	14 16 15	22 23 27		13 12 10	0	7	0	7	7	7	0	0
0959	51125	N	01289	W			X				C	X		√ √ √	10 10 8	20 20 24	16 17 16	22 23 24		13 14 10	0	7	0	7	7	7	0	3
1003	51118	N	01396	W			X				C			√ √ √	11 11 11	20 21 19	16 18 15	22 24 22		15 15 16	0	7	0	7	7	7	0	7
1008	511[illegible]	N	01483	W			X				C			√ √ √	10 11 10	20 19 19	16 17 16	22 22 22		15 15 15	0	7	0	7	7	7	0	7
1013	51097	N	02007	W			X				C			√ √ √	11 10 11	20 20 18	16 15 18	22 22 23		17 16 17	0	7	0	7	7	7	0	7
1017	51085	N	02111	W			X				C			√ √ √	10 10 8	20 18 14	16 15 18	22 24 22		16 16 15	0	7	0	7	7	7	0	7
1020	51077	N	02189	W			X				C			√ √ √	10 11 10	18 19 20	16 17 16	20 24 22		16 18 12	0	7	0	7	7	7	0	6
1024	51065	N	02288	W			X				C			√ √ √	10 11 9	18 20 20	18 15 18	22 23 22		16 18 15	0	7	0	7	7	7	0	7
1029	51054	N	02398	W			X				C			√ √ √	10 9 10	18 22 20	18 13 18	23 22 22		16 18 12	0	7	0	7	7	7	0	6
1033	51042	N	02501	W			X				C			√ √ √	10 11 9	18 16 20	18 13 17	23 24 22		17 15 12	0	7	0	7	7	7	0	6
1037	51025	N	03021	W			X				C			√ √ √	10 9 9	18 17 15	18 20 17	20 19 25		16 15 13	0	7	0	7	7	7	0	7
1043	51039	N	02512	W			X				C	X		√ √ √	10 8 10	18 15 18	16 15 18	22 22 24		13 12 12	0	7	0	7	7	7	0	1
1047	51056	N	02394	W			X				C			√ √ √	10 10 10	18 16 18	17 17 14	22 24 22		15 15 12	0	7	0	7	7	7	0	6
1050	51067	N	02288	W			X				C			√ √ √	9 11 11	19 16 18	18 15 16	23 23 24		16 18 15	0	7	0	7	7	7	0	7
1054	51078	N	02189	W			X				C			√ √ √	11 9 11	18 17 16	18 17 17	22 22 24		16 15 11	0	7	0	7	7	7	0	6
1058	51086	N	02117	W			X				C			√ √ √	11 11 11	16 18 16	16 17 17	20 22 24		16 13 12	0	7	0	7	7	7	0	4
1102	51100	N	02018	W		X	X				C			10 10 10	11 11 11	17 16 17	17 18 16	22 22 22		16 14 12	0	0	0	7	7	7	0	6
1106	51107	N	01492	W		X	X				C			7 7 7	10 11 11	17 17 15	18 17 15	22 24 26		17 18 12	0	0	0	7	7	7	0	6
1109	51119	N	01394	W		X	X				C			10 9 7	11 11 11	17 16 15	18 14 15	22 24 24		17 16 15	0	0	0	7	7	7	0	7
1114	51133	N	01285	W		X	X				C			10 11 10	11 12 9	17 14 14	18 14 13	22 24 24		17 16 13	0	0	0	7	7	7	0	7
1117	51119	N	01180	W			X				C			30 30 √	11 9 10	17 14 16	18 15 16	24 24 24		17 16 11	0	7	0	7	7	7	0	5
1121	51156	N	01061	W			X				C			√ √ √	12 9 11	15 16 16	15 14 13	24 22 22		13 14 10	0	7	0	7	6	7	0	3
1125	51166	N	00573	W			X				C			√ √ √	10 11 10	15 16 15	15 10 14	24 22 28		13 15 12	0	7	0	7	6	7	0	4
1129	51168	N	00476	W			X				C																	
					M																							

Station 1 (cols 27–29): OFF THE AIR FOR MAINTENANCE

Station 7 (cols 45–47): USED FOR ANTENNA CALIBRATION

REF. POSITION CODE 1 VISUAL REF. 2 ____ 3 ____ 4 ____ 5 ____

NOTE 1. MARK WITH X IF STATION NOT AVAILABLE, 'D' IF DESELECTED BY EQUIPMENT, 'M' IF MANUAL

NOTE 2. CIRCLE V.L.F. STATION No. IF FLASHING √ = 40

Table 3

MEGA/V.L.F REPORTING FORM

4th OMEGA TEST FLIGHT

.8C ROUTE 260°(T) AND RECIP. OBSERVER (S) I.D.B. L.E.R. PAGE 1 OF 1

QUALITY 6 (10.2 13.6 11.3) cols 42–44	QUALITY 7 (10.2 13.6 11.3) cols 45–47	QUALITY 8 (10.2 13.6 11.3) cols 48–50	STNS USED (AUX 3) 1 2 3 4 5 6 7 8 cols 51–58	V.L.F. (AUX 5) STNS (NOTE 2) cols 59–62	SIGNAL QUALITY cols 63–66	MOD N cols 67–70	REFERENCE POSITION LAT cols 71–75	N/S 76	LONG cols 77–82	E/W 83	CODE 84	QUALITY INDEX	REMARKS
20 25 10		12 14 8	0 7 0 7 7 6 0 2	1 5 6 9	8 ✓ ✓ 11	0 4 4 0	5 1 1 6 2	N	0 0 4 6 2	W	1	01	SWITCH ON
													TAKE OFF.
21 22 24		15 16 16	0 7 0 7 7 7 0 7	1 5 6 7	10 ✓ ✓ 19	0 4 4 4	5 1 1 7 1	N	0 0 4 8 3	W		01	TAS SET 92 Kn
21 21 23		15 16 15	0 7 0 7 7 7 0 7	1 5 6 7	10 ✓ ✓ 16	0 4 4 4	5 1 1 6 0	N	0 0 5 8 8	W		01	
22 22 24		13 12 12	0 7 0 7 6 7 0 1	1 5 6 7	8 ✓ ✓ ✓	0 4 4 4	5 1 1 5 2	N	0 1 0 6 1	W		01	
22 23 27		13 12 10	0 7 0 7 7 7 0 0	1 5 6 7	8 ✓ ✓ 18	0 4 4 4	5 1 1 4 0	N	0 1 1 8 0	W		01	
22 23 24		13 14 10	0 7 0 7 7 7 0 3	1 5 6 7	8 ✓ ✓ 18	0 4 4 4	5 1 1 2 9	N	0 1 2 8 5	W		01	
22 24 22		15 15 16	0 7 0 7 7 7 0 7	1 5 6 7	8 ✓ ✓ 20	0 4 4 4	5 1 1 1 7	N	0 1 4 0 0	W		00	
22 22 22		15 15 15	0 7 0 7 7 7 0 7	1 5 6 7	10 ✓ ✓ 20	0 4 4 4	5 1 1 0 7	N	0 1 4 9 5	W		01	
22 22 23		17 16 17	0 7 0 7 7 7 0 7	3 5 6 7	2 ✓ ✓ 22	0 4 4 4	5 1 0 9 2	N	0 2 0 0 0	W		01	
22 24 22		16 16 15	0 7 0 7 7 7 0 7	1 5 6 7	29 ✓ ✓ 18	0 4 4 4	5 1 0 8 1	N	0 2 1 2 4	W		01	
20 24 22		16 18 12	0 7 0 7 7 7 0 6	1 5 6 3	✓ ✓ ✓ 2	0 4 4 2	5 1 0 7 2	N	0 2 1 9 6	W		00	
22 23 22		16 18 15	0 7 0 7 7 7 0 7	1 5 6 8	✓ ✓ ✓ 7	0 4 4 2	5 1 0 6 1	N	0 2 2 9 5	W		01	
23 22 20		16 18 12	0 7 0 7 7 7 0 6	1 5 6 4	✓ ✓ ✓ 12	0 4 4 0	5 1 0 4 9	N	0 2 3 9 5	W		00	
23 24 22		17 15 12	0 7 0 7 7 7 0 6	1 5 6 7	✓ ✓ ✓ 18	0 4 4 4	5 1 0 3 5	N	0 2 5 1 4	W		01	
21 19 25		16 15 13	0 7 0 7 7 7 0 7	1 5 6 7	20 ✓ ✓ 18	0 4 4 4	5 1 0 2 0	N	0 3 0 2 5	W		01	
22 22 24		13 12 12	0 7 0 7 7 7 0 1	1 3 5 6	22 4 ✓ ✓	0 2 4 4	5 1 0 3 5	N	0 2 5 1 4	W		01	TURN TO RECIP HDG.
22 24 22		15 15 12	0 7 0 7 7 7 0 6	1 5 6 7	22 ✓ ✓ 11	0 4 4 2	5 1 0 4 9	N	0 2 3 9 5	W		01	
23 23 24		16 18 15	0 7 0 7 7 7 0 7	1 5 6 7	20 ✓ ✓ 12	0 4 4 2	5 1 0 6 1	N	0 2 2 9 5	W		00	
22 22 24		16 15 11	0 7 0 7 7 7 0 6	1 3 5 6	20 2 ✓ ✓	0 2 4 4	5 1 0 7 2	N	0 2 1 9 6	W		01	
20 22 24		16 13 12	0 7 0 7 7 7 0 4	1 5 6 8	20 ✓ ✓ 4	0 4 4 0	5 1 0 8 1	N	0 2 1 2 4	W		00	
22 22 22		16 14 12	0 0 0 7 7 7 0 6	1 5 6 8	22 ✓ ✓ 4	0 4 4 0	5 1 0 9 6	N	0 2 0 2 0	W		01	(LIBERIA (ST 2)
22 24 26		17 18 12	0 0 0 7 7 7 0 6	1 5 6 9	24 ✓ ✓ 3	0 4 4 0	5 1 1 0 7	N	0 1 4 9 5	W		00	OFF THE AIR)
22 24 24		17 16 15	0 0 0 7 7 7 0 7	1 5 6 8	19 ✓ ✓ 2	0 4 4 2	5 1 1 1 7	N	0 1 4 0 0	W		01	
22 24 24		17 16 13	0 0 0 7 7 7 0 7	1 5 6 8	14 ✓ ✓ 2	0 4 4 2	5 1 1 2 9	N	0 1 2 8 5	W		01	
24 24 24		17 16 11	0 7 0 7 7 7 0 5	1 5 6 9	14 ✓ ✓ 8	0 4 4 0	5 7 1 1 4	N	0 1 1 8 0	W		00	(LIBERIA BACK ON)
24 22 22		13 14 10	0 7 0 7 6 7 0 3	1 4 5 6	14 3 ✓ ✓	0 2 4 4	5 1 1 5 2	N	0 1 0 6 1	W		01	
24 22 20		13 15 12	0 7 0 7 6 7 0 4	1 5 6 9	10 ✓ ✓ 20	0 4 4 2	5 1 1 6 2	N	0 0 5 6 8	W		02	
							5 1 1 6 2	N	0 0 4 6 2	W		02	LAND/PARK.
											1		

USED FOR ANTENNA CALIBRATION

4 ____ 5 ____ 6 ____ 7 ____ 8 ____ 9 ____

BY EQUIPMENT, 'M' IF MANUALLY DESELECTED, 'C' IF CALIBRATION CHANNEL.

Table 4

SKIN MAPPING RESULTS SEA KING HORIZONTAL STABILISER

Aircraft No. XV 371 — Skin mapping data sheet

Aircraft heading: 010 — Aircraft: Sea King

Loop No.	Signal-to-noise ratio at △1 dB									Airframe location	Spectrum analyser bandwidth	Configuration △2
	10.2 kHz			11.33 kHz			13.6 kHz					
	N	S + N	Δ	N	S + N	Δ	N	S + N	Δ			
1	-85	-71	14	-80	-72	18	-86	-73	13	Ambient	30 Hz	Ant 50 ft from aircraft
2	-87	-67	20	-82	-68	14	-88	-70	18			
1	-85	-70		-82	-72		-87	-73		5	" "	Port engine on + all inverters
2	-88	-66		-80	-70		-87	-70				
1	-85	-70		-80	-72		-86	-73		5	" "	Both engines
2	-88	-65		-82	-68		-88	-70				GND idle
1	-83	-70		-83	-72		-85	-71		5	" "	Engage ro' rs
2	-80	-67		-82	-68		-85	-68				8
1	-83	-70		-78	-72		-70	-68		4	" "	8
2	-87	-65		-83	-68		-83	-69				

NOTES: △1 N = Noise only, S + N = signal plus noise, Δ = difference

△2 Configurations defined as follows:

1:	Engines on	5:	Lights on
2:	Generator on main	6:	Air conditioning on
3:	Generators on auxiliary	7:	Fan on
4:	Electronics on	8:	All on

REFERENCES

No.	Author	Title, etc
1	-	Aeronautical Radio Incorporated (ARINC) Characteristic 599. Mk 11 Omega Navigation System (1977)
2	-	Omega Navigation System. A presentation for the United States Navy. Litton Aero Products. Document No. 608057 (1978)
3	H.G. Hill J. Kilvington W.R. Turner	The performance of Omega and other VLF navigation systems in aircraft. RAE Technical Memorandum Rad-Nav 19 (1975)

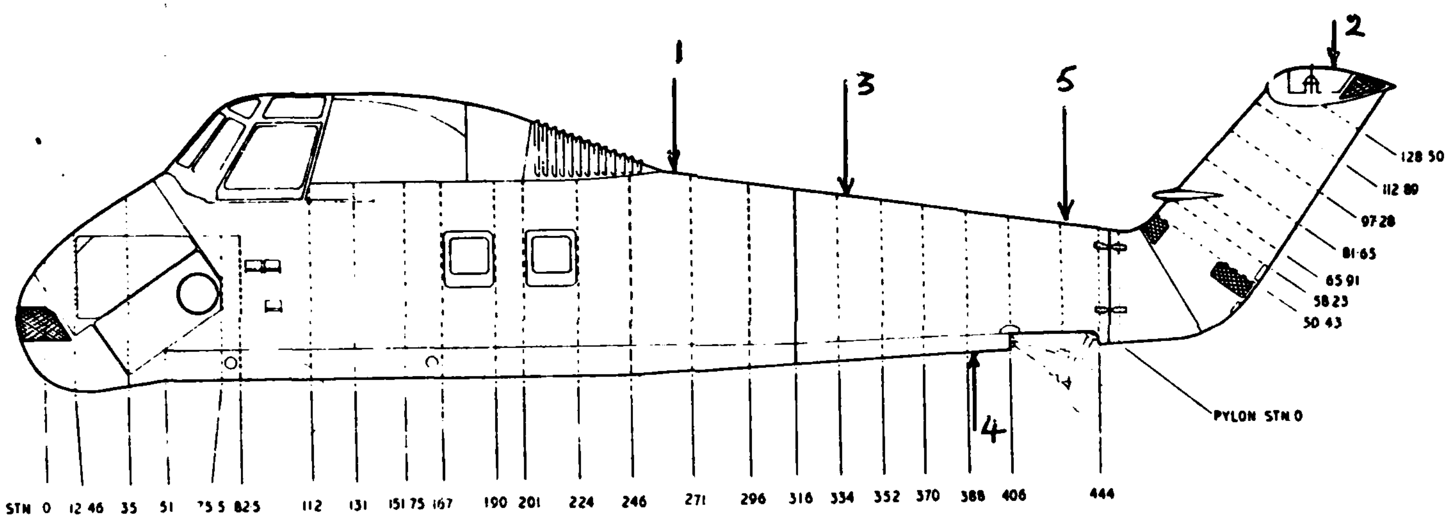

Fig 1 Wessex XL 728 skin mapping sites

Fig 2

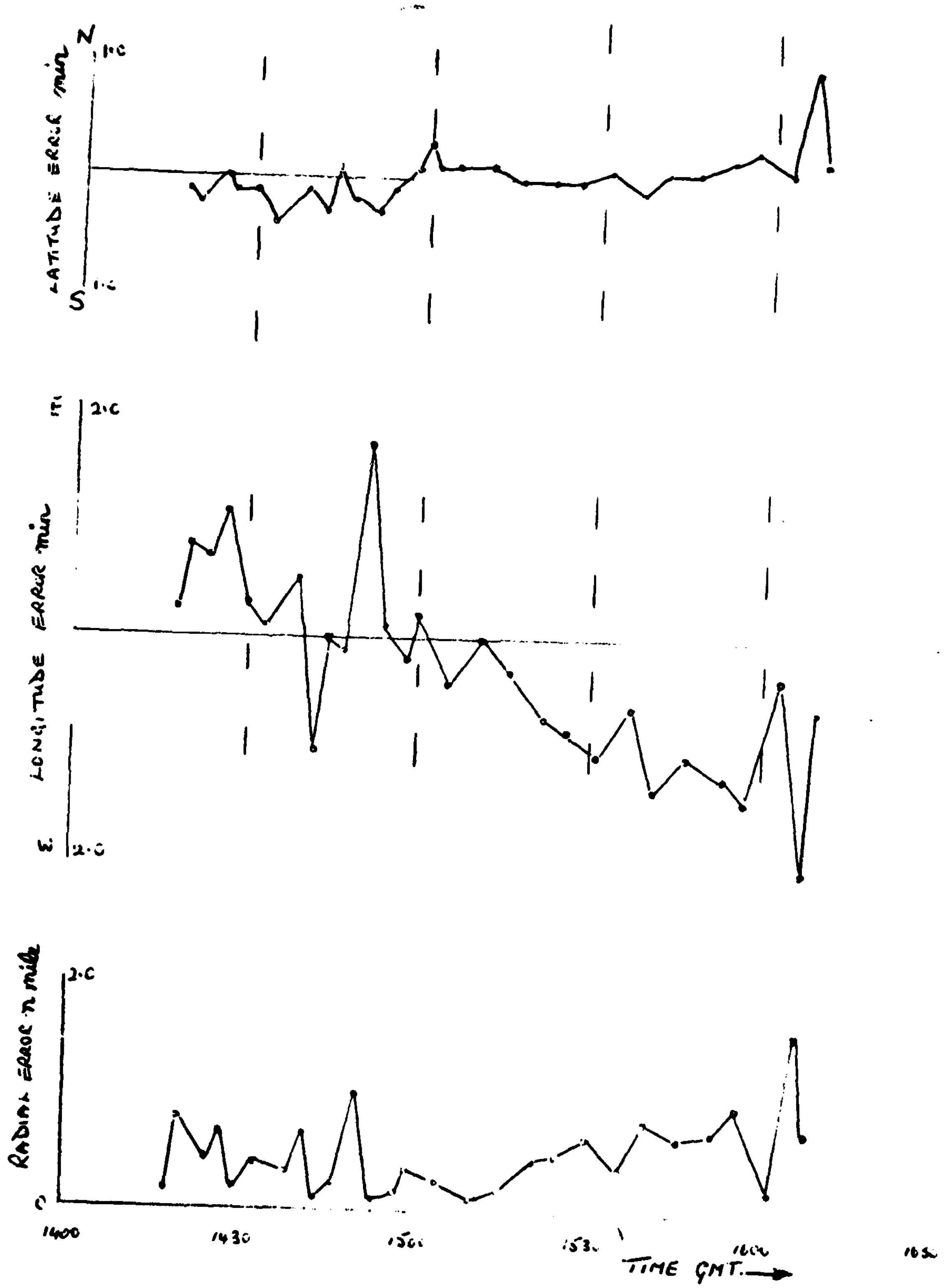

Fig 2 Accuracy plot first Wessex Omega flight 1.5.80

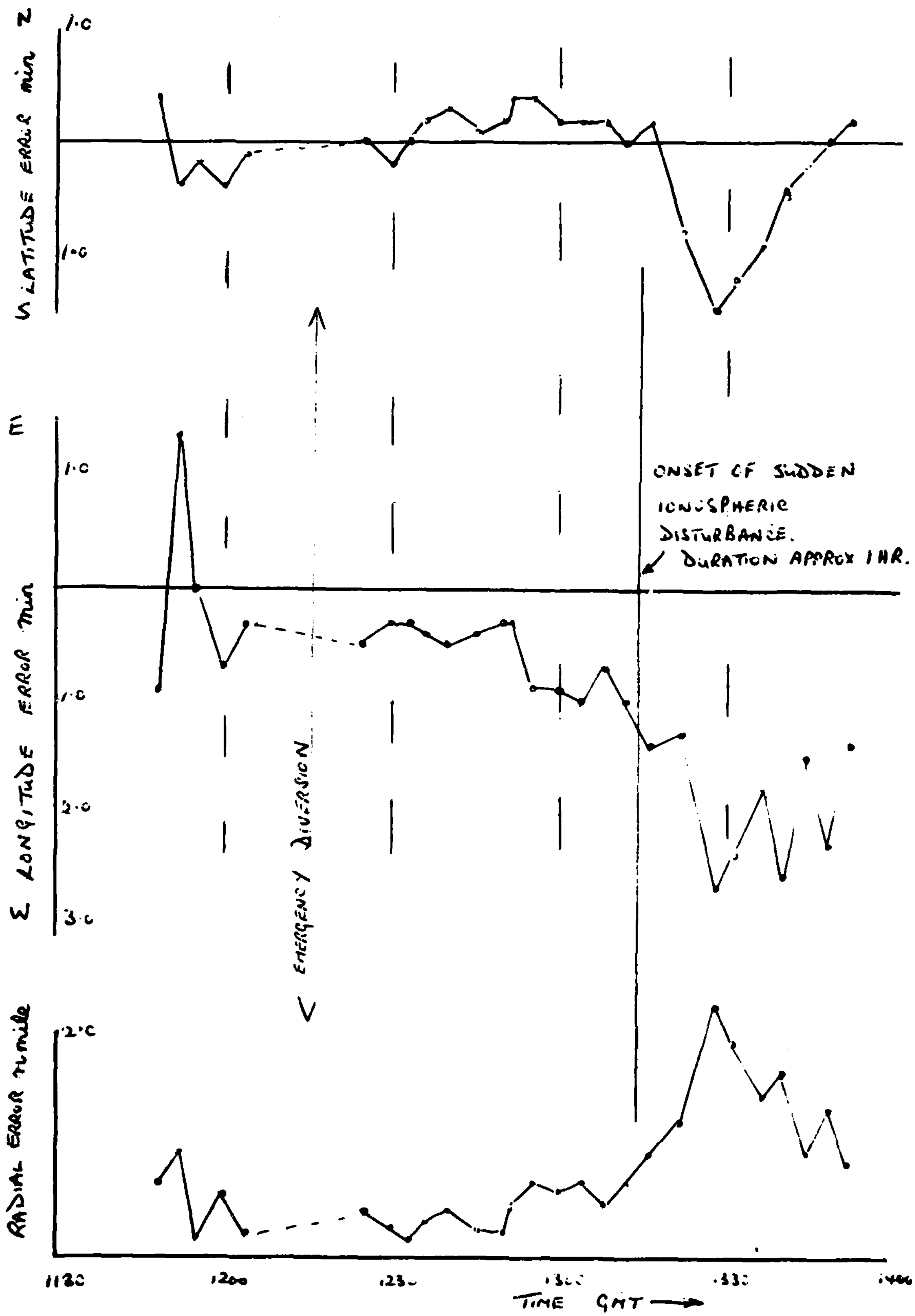

Fig 3 Accuracy plot third Wessex Omega flight 7.5.80

Fig 4

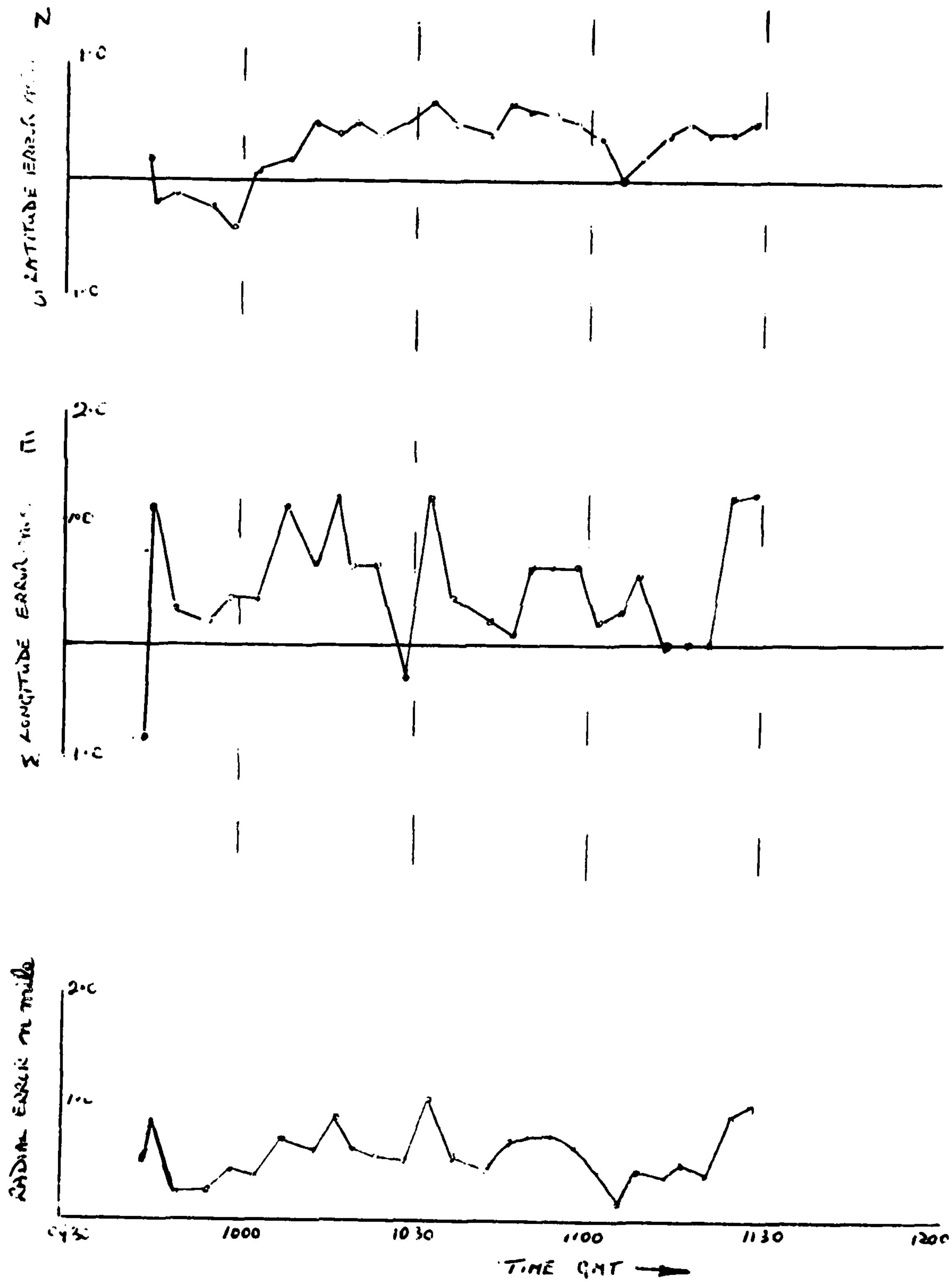

Fig 4 Accuracy plot fourth Wessex Omega flight 15.8.80

TM Rad-Nav 147

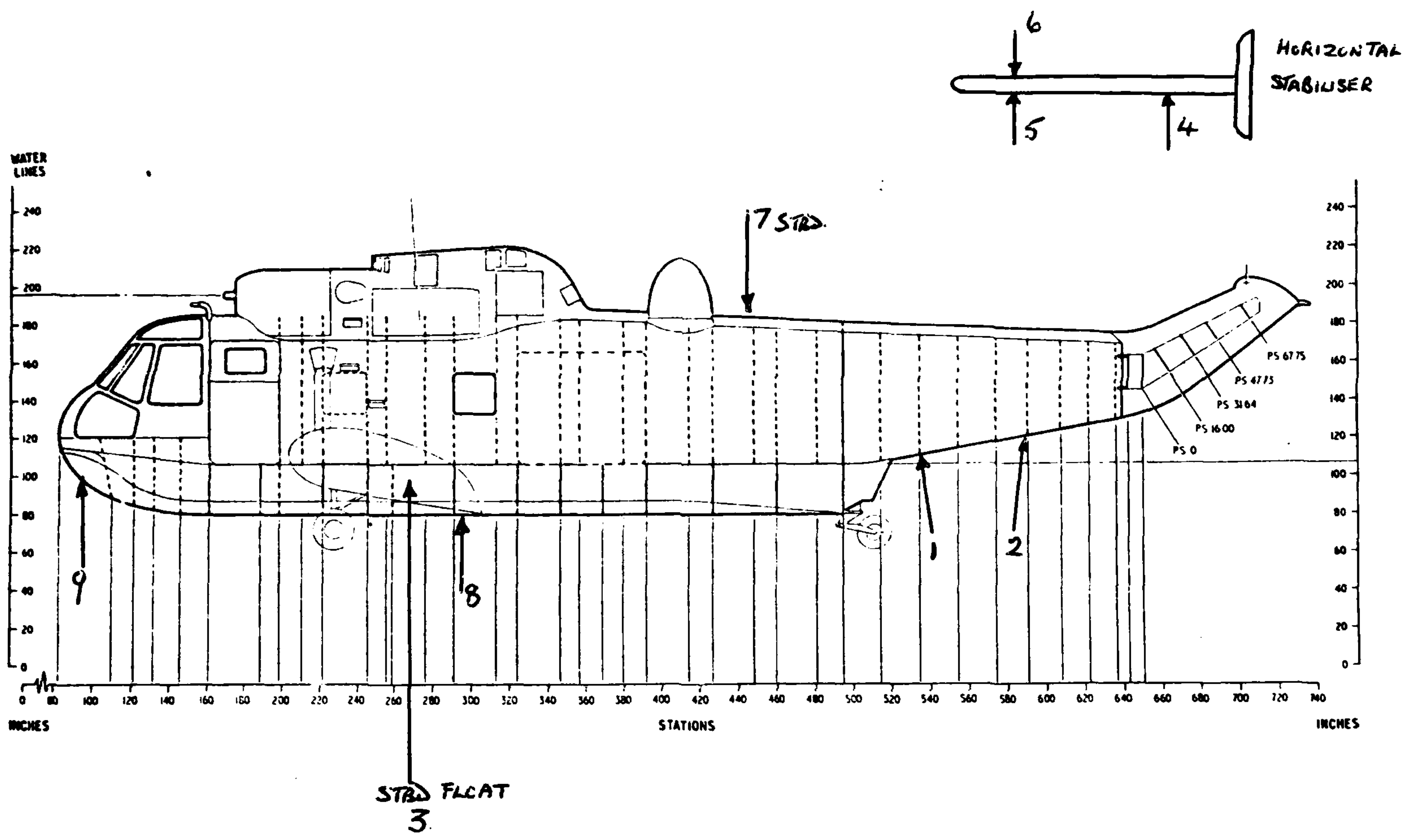

Fig 5 Sea King helicopter XV 371 skin mapping sites

REPORT DOCUMENTATION PAGE

Overall security classification of this page

UNCLASSIFIED

As far as possible this page should contain only unclassified information. If it is necessary to enter classified information, the box above must be marked to indicate the classification, e.g. Restricted, Confidential or Secret.

1. DRIC Reference (to be added by DRIC)	2. Originator's Reference	3. Agency Reference	4. Report Security Classification/Marking
	RAE TM Rad-Nav 147	N/A	UNCLASSIFIED

5. DRIC Code for Originator	6. Originator (Corporate Author) Name and Location
7673000W	Royal Aircraft Establishment, Farnborough, Hants, UK
5a. Sponsoring Agency's Code	**6a. Sponsoring Agency (Contract Authority) Name and Location**
N/A	N/A

7. Title Flight trials of the Litton LTN-211 Omega Navigation System (ONS) in a Wessex helicopter

7a. (For Translations) Title in Foreign Language

7b. (For Conference Papers) Title, Place and Date of Conference

8. Author 1. Surname, Initials	9a. Author 2	9b. Authors 3, 4	10. Date	Pages	Refs.
Birch I.D.			January 1981	19	3

11. Contract Number	12. Period	13. Project	14. Other Reference Nos.
N/A	N/A		

15. Distribution statement
   (a) Controlled by –
   (b) Special limitations (if any) –

16. Descriptors (Keywords) (Descriptors marked * are selected from TEST)

Omega navigation. VLF navigation.

17. Abstract

The Litton LTN-211 Omega Navigation System (ONS) is currently in service in RAF transport and other aircraft. This Memorandum covers installation and flight trials of a variant of the Service Omega equipment in a Wessex helicopter.